Advanced Lead Based Active Materials for Critical Battery Applications

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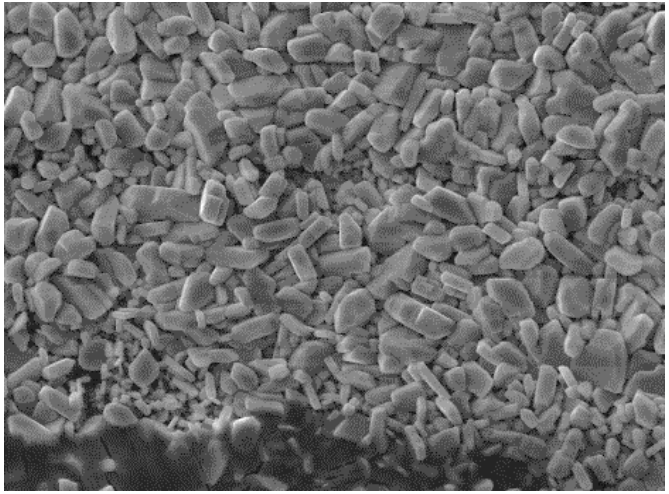
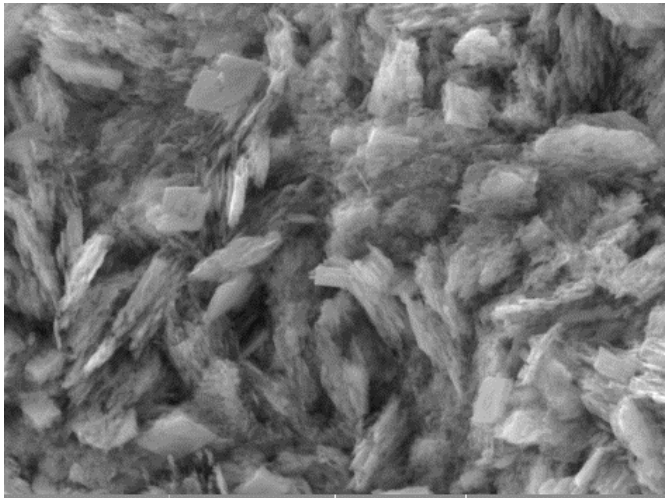
Dallas, TX

Structure Defines Properties: Better Structure = Better Batteries



Typically lead sulfate grows over the life of a lead acid battery limiting performance, i.e. dense faceted orthorhombic crystals



SUPERSOFT-HYCYCLE™ stimulates the formation of platelets composed as bundles of $PbSO_4$ nanorods. Performance is increased by >2X

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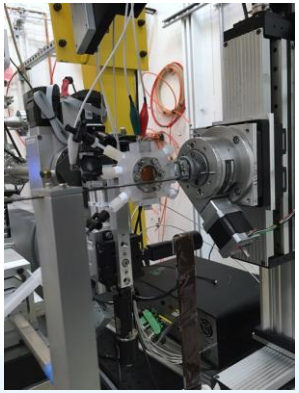
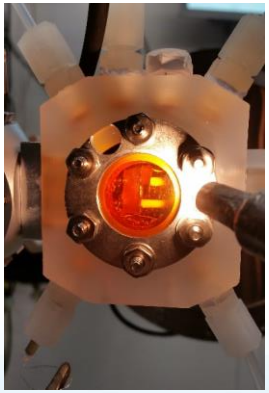
Work @ Advanced Photon Source

Argonne National Laboratory

- Argonne National Laboratory
  - Joint Center for Energy Storage Research (JCESR)
  - Argonne Collaborative Center for Energy Storage Science. (ACCESS)
- Real Time analysis of Pb-Acid batteries, an extension of techniques developed for Li ion and other systems
- The APS is one of the worlds premier facilities, the brightest tunable beam with multiple techniques in hand
- CRADA's
  - East Penn Mfg. and RSR Technologies est. Jan 2017 in qualification
  - US members of the ALABC, results 4th qtr. 2018





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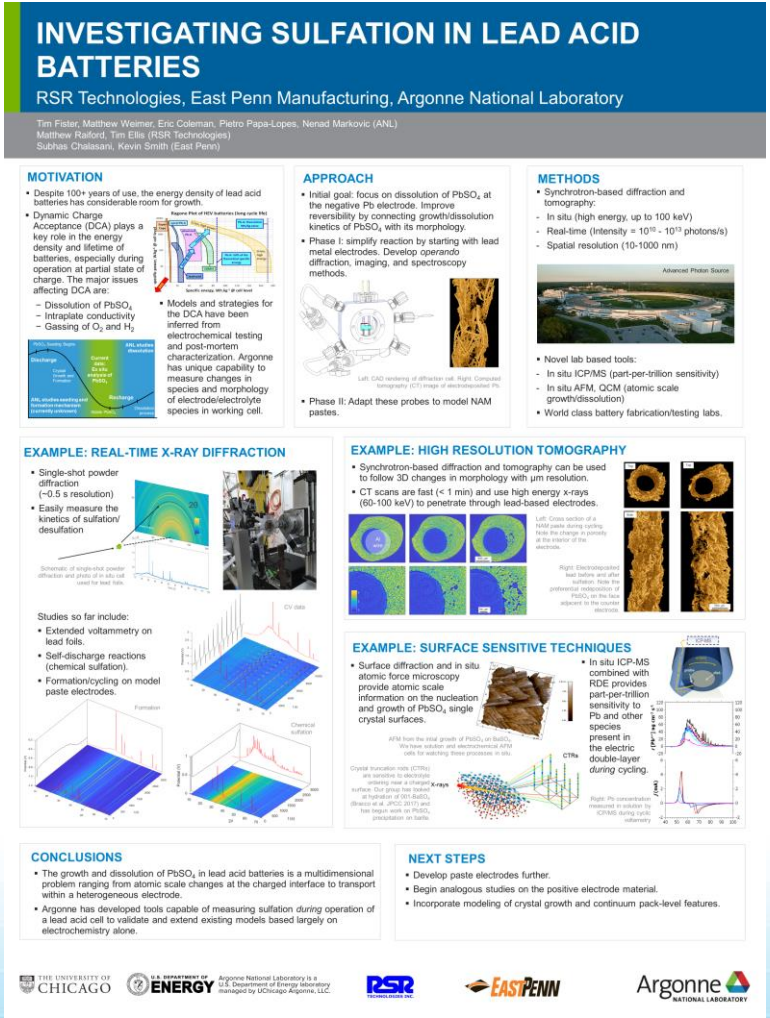
Results to Market

- Incorporated in SUPERSOFT-HYCYCLE™ product in product qualification testing
- Presented at “Battery Day” at ANL June 14th, 2017
- Invited to the “BASIC RESEARCH NEEDS WORKSHOP ON NEXT GENERATION ELECTRICAL ENERGY STORAGE” sponsored by the USDoE’s Office of Basic Energy Sciences Battery Workshop



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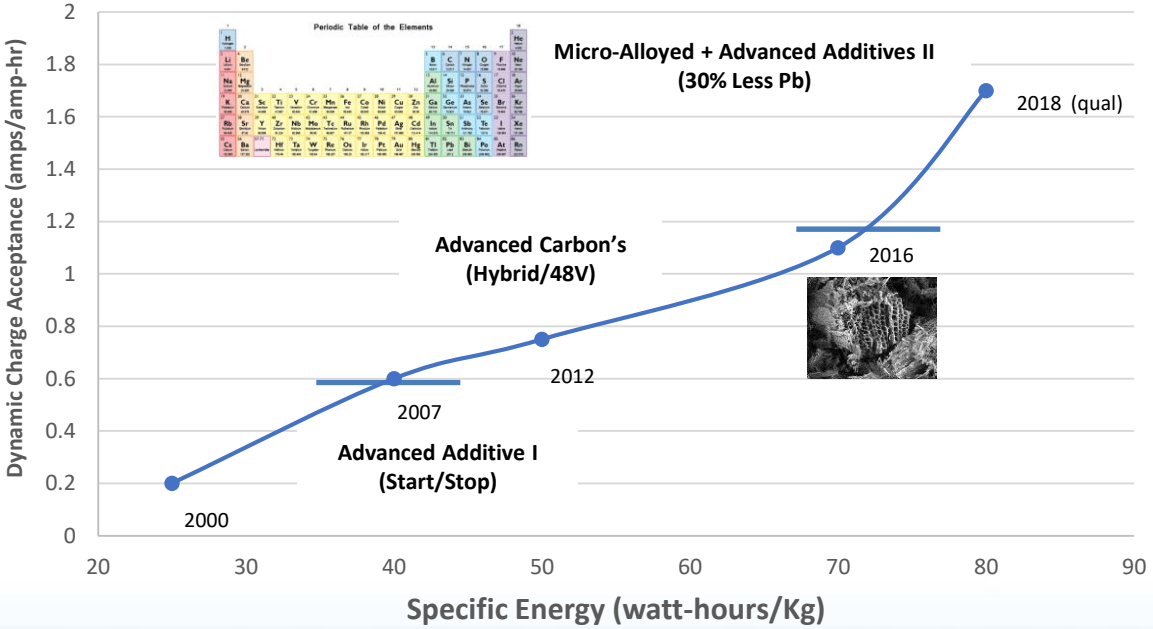
Progress in Performance



Continue product improvement improved chemistry & additives

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CPHRI Lead Battery Pilot Programs

- Advanced Battery Concepts: Workplace and Environmental Manufacturing Emissions Reduction through Green-Seal® Manufacturing Techniques

- Hammond Group Inc.: Improved Charge Acceptance for Group 31 Bus Batteries and Improved Charge Efficiency on Deep Cycle Batteries

- Doe Run: Flubor Hydrometallurgical Process for the Recycling of Pb-Acid Battery Scrap

Lead Based Energy Storage

- Improvements from research programs increase performance allowing significant reduction in lead content and longer cycle life, = Less Lead/Kw-hr
- Cost-effective displacement of fossil fuel based energy sources in transportation, grid storage and behind the meter applications, = Lower energy cost/Kw-hr and Lower emissions/Kw-hr
- Opportunities for further emission reductions associated with lead battery manufacturing and/or recycling, continue to lower the externalities of Lead usage
- True market-ready drop-in replacement with no compatibility issues, safety issues or need for more complex systems (i.e., to manage multiple chemistries).

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smart energy storage

Thank You

USDoE forward looking metrics

- Cost <$80/kw-hr (acquisition) = cost of hydrocarbon fuel
- Per Cycle cost <<$0.10/kw-hr per cycle (operational cost)
- Recharge from 20% -> 80% <20 minutes
- Puts rechargeable energy = fossil fuels

Technology Agnostic, batteries are one possible avenue

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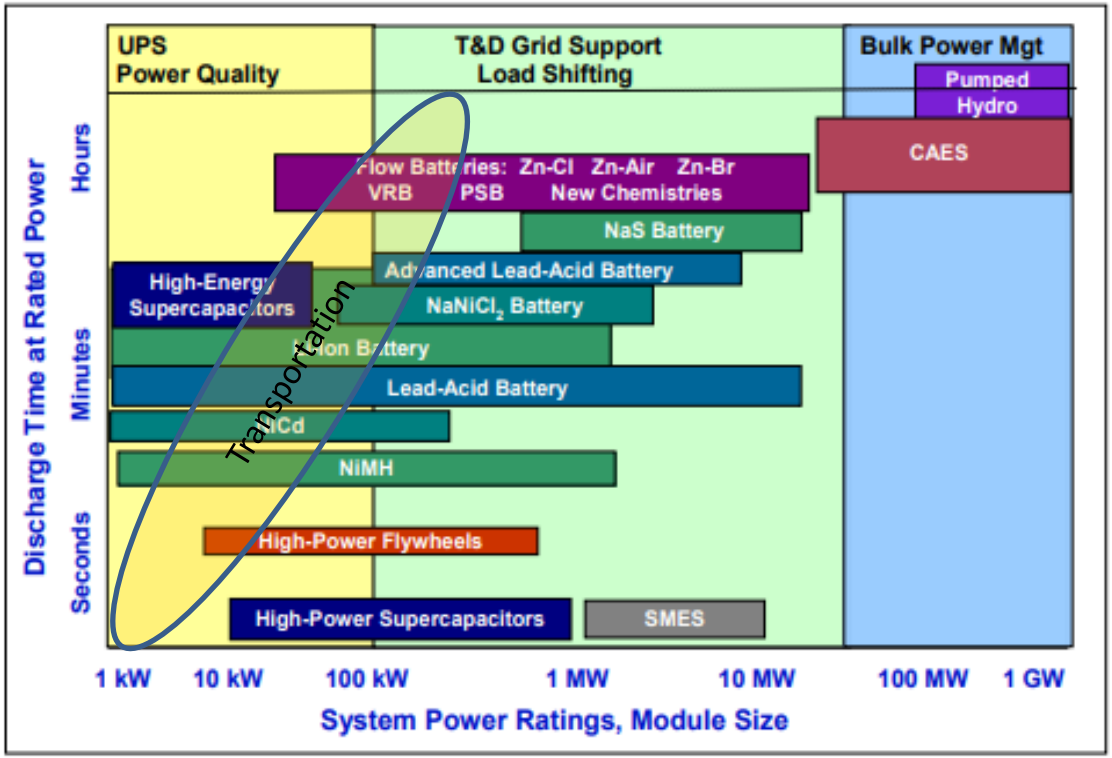
One Chemistry for Societies Applications



DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA

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Cost of Ownership Comparison

	STOP-START	MICRO HYBRID	MILD HYBRID	FULL HYBRID	PLUG-IN HYBRID	ELECTRIC VEHICLE
Idle Elimination	✓	✓	✓	✓	✓	✓
Regenerative Braking		✓	✓	✓	✓	✓
Acceleration Boost			✓	✓	✓	✓
Electric-only drive				✓	✓	✓
Electric motor power			10-20 kWh	30-40 kWh	50 kWh	above 80 kWh
Preferred primary battery	lead acid	lead acid	Li+	Li+	Li +	Li+
Annual gasoline savings	20	45	260	300	450	600
Annual CO_2 abatement (kg)	212	477	2756	3180	4770	6360
Implementation cost	350	900	4500	8000	12500	14000
Cost Recovery (years)	1	2.5	6	9	8	10

*Based on 15,000 miles a year, $3.00 per gallon of gasoline. Study was of consumer level cars under approximately $35,000 MSRP.

Average age of US Vehicle Fleet = ~ 11.5 years

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Advanced Lead Acid Battery Consortium (ALABC)

- International consortium of 77 companies
- Leading development of technology for Pb-Acid
- Leading activities drivetrain development
  - Stop/Start: Gas, Diesel, NGV
  - 12V/48V/200V Mild/Micro hybrid systems
  - Electric supercharging & turboelectric energy recovery
- Partners
  - Ford, Hyundai, USDoE, Valeo, AVL Schrick, AGL Resource, Southern California Gas, Ricardo, UK Technology Strategy Board

The LC SuperHybrid Project

Utilizes advanced lead-carbon batteries along with a belt-driven Integrated Starter Generator and an electric supercharger to increase battery charge and engine efficiency, lower carbon emissions and boost performance in 12V and 48V mild/micro hybrid vehicles.

The Natural Gas Hybrid Vehicle

Combines advanced lead-carbon batteries with a natural gas-powered engine and a factory-built start-stop system in a RAM truck to achieve lower emissions and reduced fuel costs, giving fleet owners a low-cost alternative to conventional trucks.

The ADEPT Project

Applies 48V "intelligent electrification" concepts using advanced lead batteries to deliver full hybrid equivalent fuel economy and performance with lower CO2 emissions at a significantly lower cost.

The Kia Optima T-Hybrid

Offers a 48V micro/mild-hybrid propulsion system featuring advanced lead-carbon batteries similar to the LC SuperHybrid concept and is the first of its kind to be demonstrated in collaboration with a major automaker.

The UltraBattery Civic

Demonstrated that lead-carbon UltraBatteries can out-perform Nickel Metal Hydride batteries in mild hybrids (with start-stop) by running for 160,000 miles in real-world courier duty at varying temperatures with no significant power loss.

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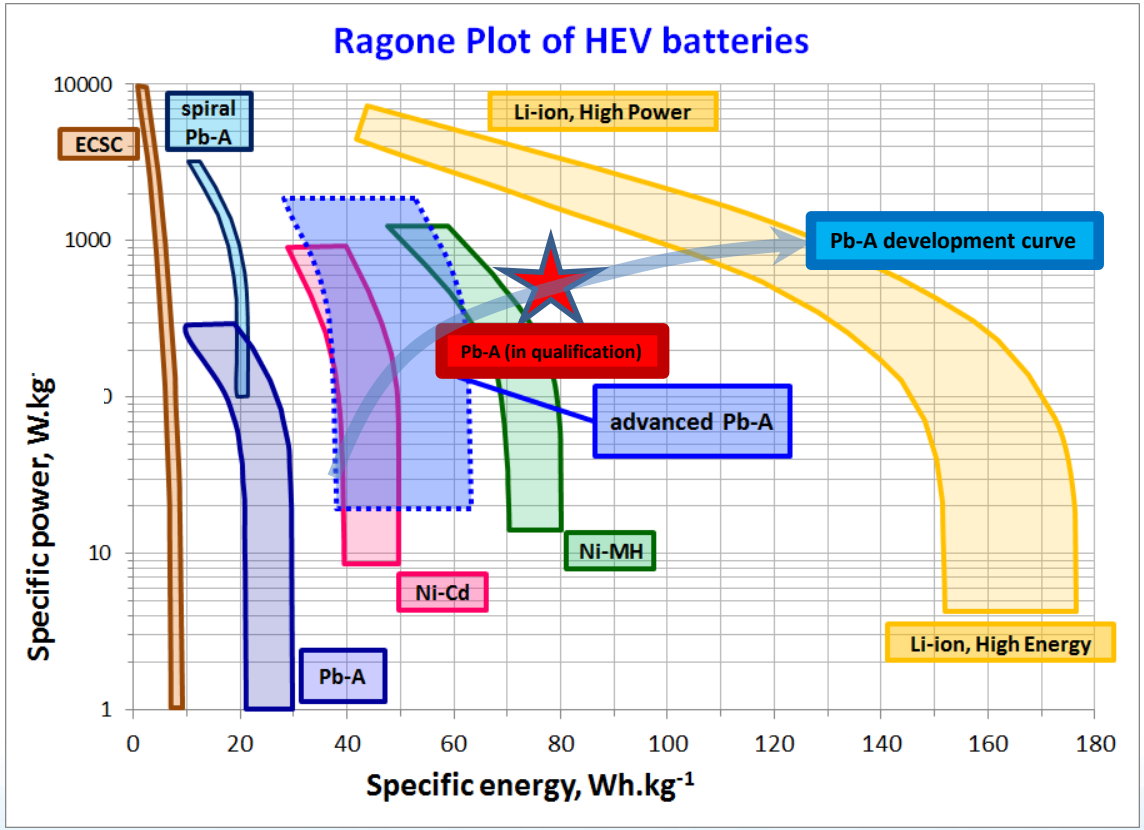
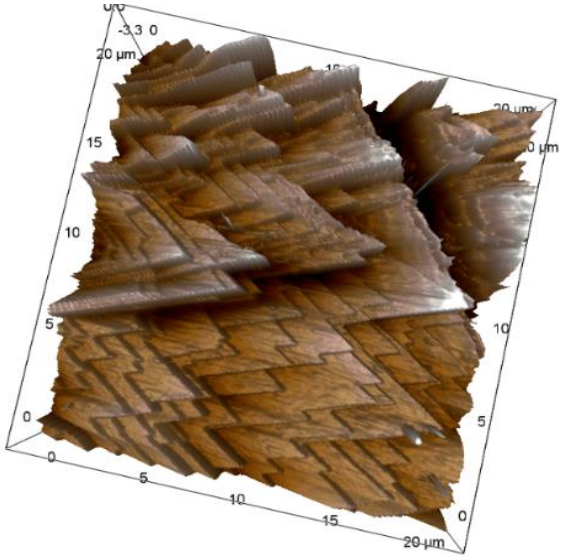
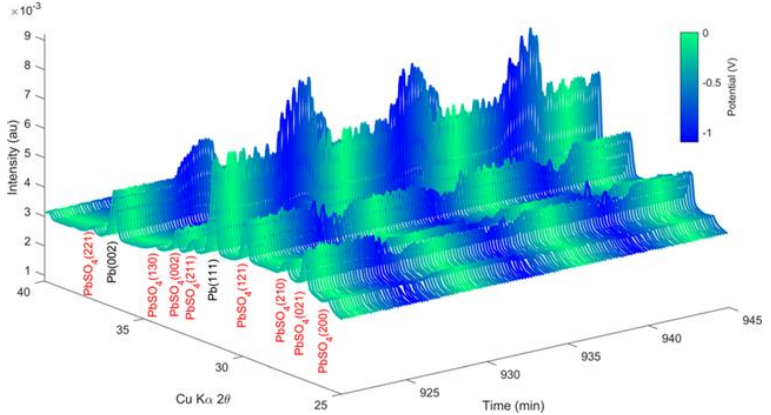
Improvement in Pb Utilization in batteries



What do we see?





Dynamic changes over time

The Crystals are Complex and Change During Use, Critical Results to Improve Performance

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